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ECONOMIC BENEFITS OF COMPOSITE SLAB SYSTEMS FOR BUILDING CONSTRUCTIONS

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ABSTRACT

The steel framed composite floor structure using cold-formed trapezoidal steel deck profiles are used in almost all multi-storey building due to their faster rate of construction, economical attractive and an alternative to structural floor systems.

This article presents economic advantages of composite floor with alternative RCC flat slab floor structure. A case study is considered for G+9 storied multilevel cars parking building at Pune. A major feature of this building is post-tensioned composite steel beams having span of 16m. The design and cost estimation is carried out on the same building plan for both composite and flat slab floor construction using relevant Codes. While designing the above structure with RCC structure, one additional column is introduced in between 16m span lengths to the overall plan to suit the design criterion. The Microsoft Project-2010 software used for time scheduling and the required optimum time at different stages are calculated. The total cost of both structures is calculated as material and construction costs of each structural element only. The results obtained in terms of cost and time. The results shows that the steel frame with composite deck floor required 7.69 % extra cost than RCC structure with flat slab floor, which saves 189 % of total construction time.

KEYWORDS: Composite Floor Construction, Post-Tensioned Composite Beam, Rcc Flat Slab Floor, Time Scheduling, Cost Evaluation

1. INTRODUCTION

One of the biggest revolutions came with introduction of hot-rolled steel section and cold-formed profiled steel decking as a construction material for high rise structures. Steel framed structures with composite floor would bring considerable economies to the overall cost of the project during its lifetime [1]. The increased popularity of steel framed construction over the last three decades is due to the advantages arising from the use of composite floor. It is lighter and cheaper from the scenario of construction in US. However, this would get expensive if constructed in India. However, the slight higher price gives an efficient system over a flat slab.

The flat slab building provides many advantages in terms of architectural flexibility, use of space, easier formwork and shorter construction time for use in commercial buildings. Flat slab systems become dominant form of construction from past few years for use in commercial buildings. To overcome limitations of conventional RCC flat slab structure came

in to existence and was a very timely solution for many working problems. RCC flat slabs are used normally for spans up to 9m and are particularly suited to square grids. For longer spans, the slabs are often post- tensioned.

S.J. Hicks and R.M. Lawson [2] presents a cost comparative study of two typical modern commercial building constructions. Building A is a four-storey office building in Manchester with a gross floor area of 2600 m^2. Building B is an eight-storey prestige company headquarters in London with a gross floor area of 18000 m^2. The speed of construction for building A, the steel structural systems is erected in 6 weeks, compared with 8 weeks for precast systems and for building B, the steel options took 13 weeks whereas precast systems required 25 weeks. The variations in total cost of all the steel-based options are relatively small and are considerably cheaper than the concrete based systems.

Davis Langdon [3] found in his study 2.32% saving with steel framed composite floor structure compared to RCC structure with post-tensioned flat slab for construction of 12 storeys high building with a gross floor area of 25000 m^2 in London, UK. The comparison does not include consideration of time benefits.

2. BUILDING CONSTRUCTION DETAILS

A G+9 storied multilevel car parking composite building construction is considered for case study (Figure 1). The plan dimension is 50 m x 64 m. In this case, the arrangement found in composite slab systems is a post-tensioned composite steel beam connected to a profiled steel metal deck and concrete slab. The profiled steel deck made from 1 mm cold rolled steel as per IS 277. The spans are 11.5 m long and 0.954 m wide which supports and acts as reinforcement in composite floor. The deck properties are calculated from the Steel Deck design manual [4]. The design of composite floor systems is carried out by considering the data required for the structural analysis of existing building plan using Eurocode-4 [5].

The design of RC flat slab floor structure is done using relevant IS Codes [6], keeping the same above plan, total floor area, floor-to-floor height and loading conditions (live loads and superimposed dead loads) are kept constant similar to the design data of existing steel framed composite floor structure. The structural members of the building *viz.* beam, column and slab are designed and constructed as RC flat slab floor structure. In RCC structure it is not possible to keep span up to 16m unless any intermediate column or a large RC beam is necessary to introduced in between columns (Figure 3).

The optimum time duration and total cost required for the construction are important factors for comparing the economical studies of steel framed composite floor and RCC flat slab floor structures. The Microsoft Project-2010 software [7] is used for calculation of optimum time duration. The material estimates for the construction of structural elements as well as its costing and construction cost are prepared from the structural drawings based on current rates for the year 2013 [8].

Figure 1: Multilevel Car Parking Steel Framed Composite Floor Structure

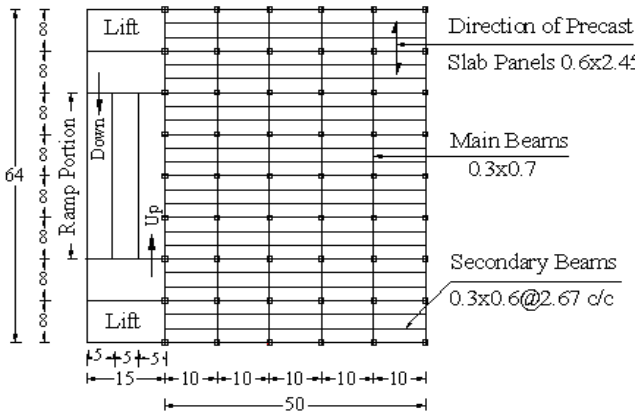


Figure 2: Typical Plan of Multilevel Car Parking Structure

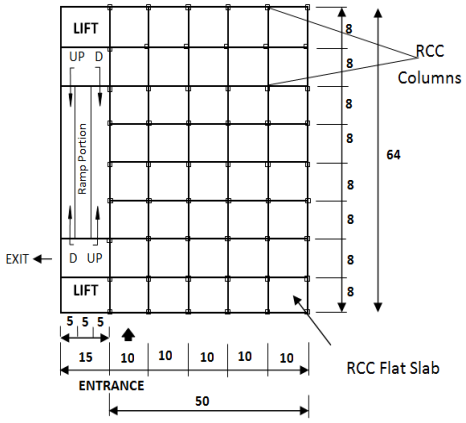


Figure 3: Typical Plan of RCC Flat Slab Floor Structure

3. SALILENT FRATURES OF MULTILEVEL CAR PARKING STRUCTURE

- Thin-walled cold-formed profiled steel decks are used as a permanent shuttering material in this building and building completion is achieved within seven months only.
- The four wheeler vehicles parking capacity is 2000/10 hrs/day for regular morning shift and 1000/10 hrs/day for night shift. The total capacity of parking is 3000/day.
- This building is combination of both form of steel is used i.e. hot rolled steel sections (structural steel) and cold-formed steel (profiled steel decks in composite floor).

4. CONSTRUCTION METHODOLOGY OF STEEL FRAMED COMPOSITE FLOOR STRUCTURE

4.1. RCC Pedestals

The foundation consists of RCC pedestals that are aligned with the columns. For fixing anchor bolts pedestal casting is done in two stages. Anchor bolts are necessary to hold huge steel columns in a position. Length of anchor bolts is 1200 mm. Special arrangement is done to hold bolts while casting. In G+9 storied building heavily loaded columns results large footing sizes.

4.2. Erection of Columns and Beams

Erection of columns & beams of this building can be done in four stages. As shown in Figure 4 (a & b), first lift erection includes the ground, first and second floor columns and beams. No other activities simultaneously carried out on these three floors, unless total erection of columns & beams for first lift is completed. Second lift erection is started after completing first lift erection and at the same time the construction of ground, first and second level slab with step-by-step procedure as per the drawing details are in a progress. By following the same above construction procedure, the remaining 3rd and 4th lift can be erected simultaneously and it gives better understanding about the time scheduling.

4.3. Construction of Composites Slab Floor

After the complete erection of steel columns and beams upto the 3rd floor, the simultaneous construction works can be start from 1st to 3rd floor for 1st lift of the building. In this works, the laying of profiled metal decks, shear stud welding and reinforcement with concreting for 3rd, 2nd and 1st floor respectively is in progress. This methodology allows

many construction activities starts simultaneously in steel framed composite structures only and finally the time required for the construction can be saved. The design section of composite slab with all details is shown in Figure 5 [5, 9].

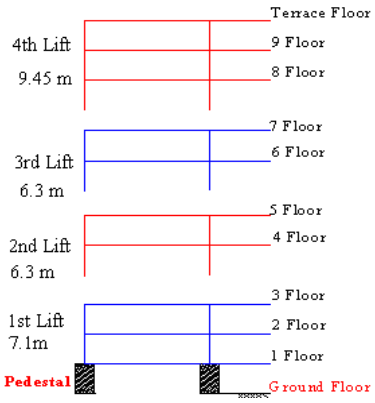


Figure 4a: Lift Wise Erections of Columns and Beams

Figure 4b: Erected Frame after 1st Lift

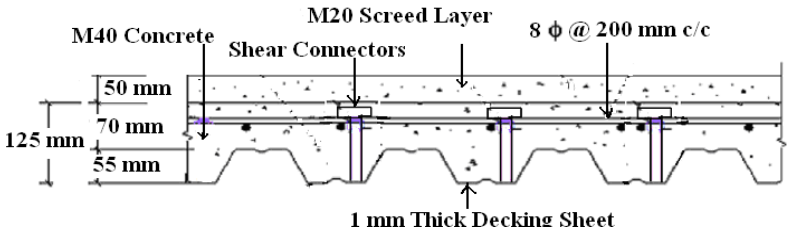


Figure 5: Section of Composite Floor Slab

4.4. Post-Tensioning of Steel Beams

For main and secondary beams, six and two cables on both side of beam respectively are fixed. In shorter and longer direction, cables are tensioned for five and four spans respectively as shown in Figure 6. The post-tensioning method is divided into three stages. At 14, 21 and 28 days of slab casting, the beam will take 50%, 75% and 100% load respectively when the concrete reached as its maximum compressive strength after 28 days.

Figure 6a: Post-Tensioning Cables at Column Junction

Figure 6b: Post-Tensioning Cable through Beams

5. CONSTRUCTION METHODOLOGY OF RCC STRUCTURE WITH FLAT SLAB FLOOR

The structural analysis of RC structure flat slab structure is carried by using STAAD-Pro software [10]. In this structure, the number of RCC footings is increased due to intermediate columns along longer span, which results grid size

8m x 10m. Generally for such heavy grid size slabs are often post-tensioned, but here we go for conventional flat slab structure. Figure 7 shows a typical design section of RCC flat slab with reinforcement details. Drop size is (3.4m x 2.7m), thickness of slab is 315 mm and drop thickness is 150 mm [6]. In this structure due to heavy slab thickness formwork becomes a major component and requires huge attention.

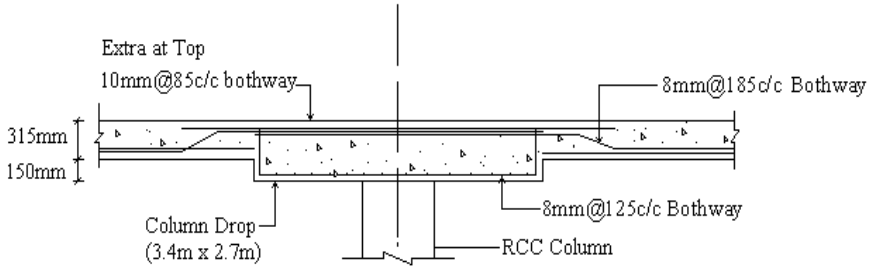
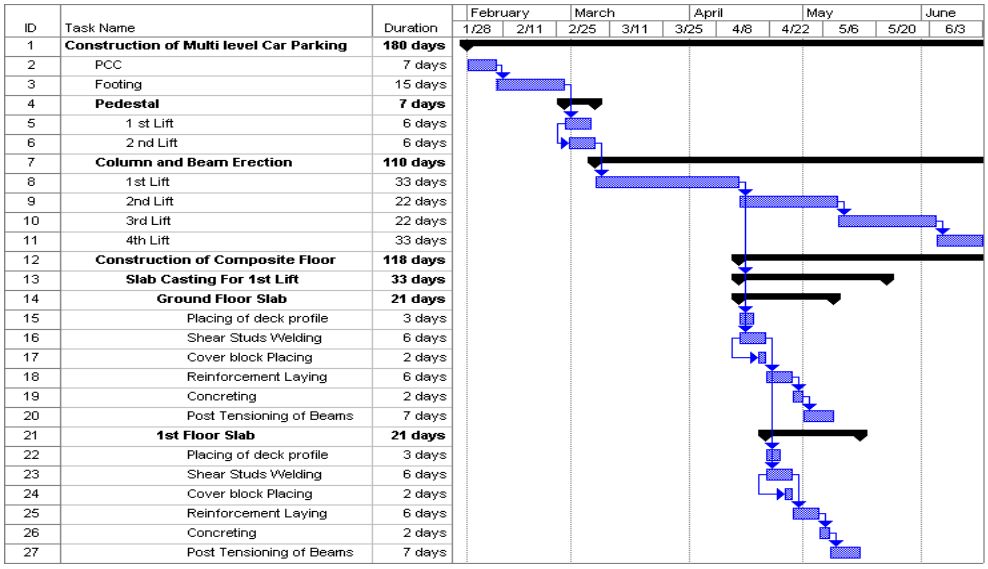


Figure 7: Section of RCC Flat Slab Structure

6. TIME SCHEDULING

6.1. Steel Framed with Composite Floor (Multilevel car Parking Structure)

Time scheduling is done using Microsoft Project 2010 Software [7]. In time scheduling some starting activities such as PCC (7 days), Footing (15 days), and Pedestal (7 days) goes individually but after completing column & beam erections for first lift (33 days), activities for composite floor construction goes simultaneously with second lift erection. Likewise whole structure can be erected with; so many work faces open together. For the construction of composite floor for all levels, requires 118 days as per time scheduling. It shows that ground & first floor slab activities and for all remaining floors activities are same as first floor. Considering time required for all floors, the building is completed in 180 working days (Figure 9). Total 210 days are required including holidays.



ID	Task Name	Duration
1	**Construction of Multi level Car Parking**	**180 days**
2	PCC	7 days
3	Footing	15 days
4	**Pedestal**	**7 days**
5	1 st Lift	6 days
6	2 nd Lift	6 days
7	**Column and Beam Erection**	**110 days**
8	1st Lift	33 days
9	2nd Lift	22 days
10	3rd Lift	22 days
11	4th Lift	33 days
12	**Construction of Composite Floor**	**118 days**
13	**Slab Casting For 1st Lift**	**33 days**
14	**Ground Floor Slab**	**21 days**
15	Placing of deck profile	3 days
16	Shear Studs Welding	6 days
17	Cover block Placing	2 days
18	Reinforcement Laying	6 days
19	Concreting	2 days
20	Post Tensioning of Beams	7 days
21	**1st Floor Slab**	**21 days**
22	Placing of deck profile	3 days
23	Shear Studs Welding	6 days
24	Cover block Placing	2 days
25	Reinforcement Laying	6 days
26	Concreting	2 days
27	Post Tensioning of Beams	7 days

Figure 8: Time Scheduling for Steel Framed Composite Floor Structure

6.2. RCC Structure with Flat Slab Floor

In reinforced concrete cast in situ structure, slab preparation activity takes lot of time. Duration of this activity goes on increasing as structure progress upwards.

ID	Task Name	Duration
1	**Construction of Multilevel Car Parking**	**462 days**
2	PCC	6 days
3	Footing	20 days
4	**Ground Floor**	**32 days**
5	Column Prerparatin	15 days
6	Column Casting	14 days
7	Slab Preparation	20 days
8	Slab Casting-I	5 days
9	Slab Casitng-II	5 days
10	**1st Floor**	**35 days**
11	Column Prerparatin	15 days
12	Column Casting	14 days
13	Slab Preparation	23 days
14	Slab Casting-I	5 days
15	Slab Casitng-II	5 days
16	**2nd Floor**	**38 days**
17	Column Prerparatin	15 days
18	Column Casting	14 days
19	Slab Preparation	26 days
20	Slab Casting-I	5 days
21	Slab Casitng-II	5 days

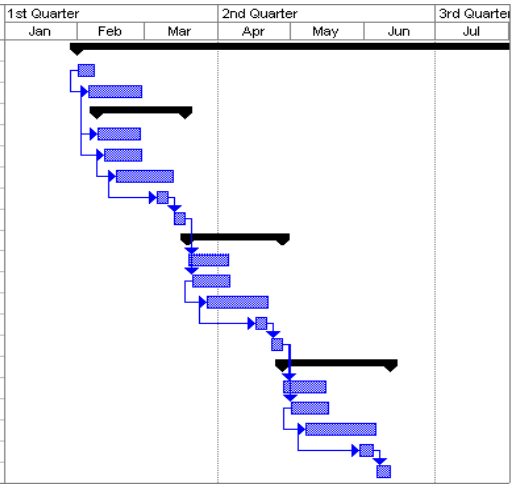


Figure 9: Time Scheduling for RCC Flat Slab Structure

Each floor slab duration increased by three days than duration required for next lower slab. As PCC activity started after seventh day only ground floor activities are started as mention in Figure 9. Figure shows activities up to second floor. Activities for remaining floor are same as first floor. For completion of work 462 working days is required (7+32+35+38+41+44+47+50+53+56+59) & total 539 days are required including holidays.

In steel framed composite floor structure erection is done in a four lifts, it is not possible to do floor wise comparison. So for comparison purpose RCC structure is divided into four lifts. The time scheduling is carried by considering same starting date for all type of construction methods as 1st February 2013, which results into balancing of holidays, working and non-working days.

With steel framed composite structure huge time saving is achieved. In RCC flat slab structure, as structure progresses, days required to complete each floor are goes on increasing. But in steel framed composite floor structure this difference is very much less; so project completion with such system achieved within very less duration. The construction of multi-storeyed car parking building with steel frame composite deck floor (210 days) saves 189% time than RCC structure with flat slab floor (539 days) (Figure 10).

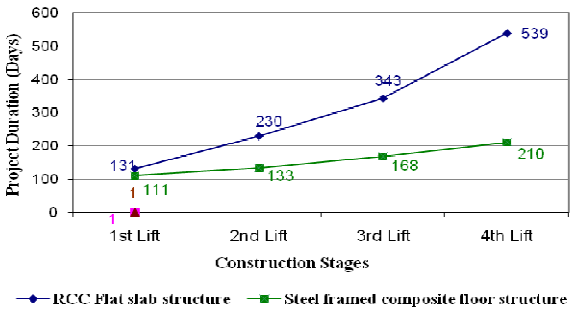


Figure 10: Lift Wise Comparison for the Structures

7. COST ESTIMATION

7.1. Direct cost of projects

The total cost of project is divided into major construction activities as, cost of foundations, columns, beams and slabs construction. It is observed that for the steel frame with composite floor structure, the maximum material cost is

associated with beams and slabs material and maximum construction cost is associated with erection of post-tensioned beam. About 83.56% of total cost of structure is the cost of beams & slabs material and its erection (Figure 11). And about 16.14% of total cost of structure is the cost of columns & footings material and its erection (Figure 12).

Similarly for RCC structure with flat slab floor, about 80.56% of total cost of structure is the cost of beams & slabs material and its erection and about 19.44% of total cost of structure is the cost of columns & footings material and its erection. In both structures major share is for slabs & beams.

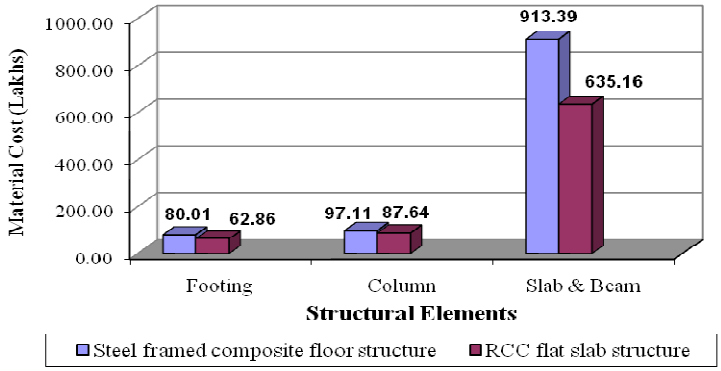


Figure 11: Material Cost of Structures

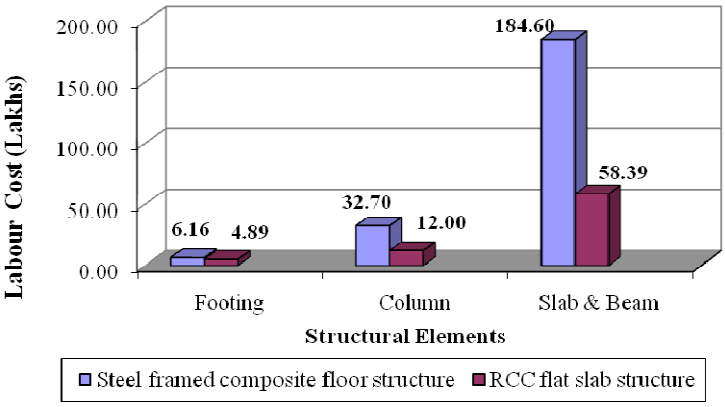


Figure 12: Construction Cost of Structures

The cost for foundation and column in both building is least amount as evaluated with cost of beams and slabs construction. The cost of large span post-tensioning composite steel beam affect on the total project cost, project cost increased by 11% of total cost of project. The higher cost of steel building is attributed to cost of steel being higher than concrete.

7.2. Extra Cost for Structures

The extra cost of projects are calculated and compared by considering time related saving, the interest cost on barrowing money and the cost required for car parking rent for saved days of construction. The extra costs of projects are calculated based on interest rate and parking charges in Table 1.

7.2.1. Interest Rate

By taking the survey of various banks and some reputed construction companies, the data for interest rate on the barrowing money is collected and the average interest rate for commercial constructions is considered as 11%.

7.2.2. Parking Charges

- Parking charges at multilevel car parking building decided by Infosys: Rs. 900/- per month per vehicle.
- **Parking Capacity**: 3000 vehicles per day *(as mention in section-3)*
- Extra cost required for car parking rent for saved days,

  = Days saved in construction x *No. of vehicles* x *parking charges /30*

Table 1: Extra Cost for Structures

Sr. No	Cost Descriptions	Steel Frame with Composite Floor Structure	RCC Flat Slab Floor Structure
1	Direct cost (Lakhs)	1297.37	860.94
2	Total project duration (Days)	210	539
3	11 % interest on Direct cost (Lakhs)	82.12	140.10
4	Cost required for car parking rent for saved days (Lakhs)	-	296.19
5	Total net cost (Lakhs)	1379.48	1297.24
6	Total net cost (Rs/m^2)	4310.00	4054.00
7	Extra cost required for steel frame with composite deck floor structure (Rs)		312.00
8	Extra cost required for composite structure over RCC structure considering net cost (%)		7.69

8. CONCLUSIONS

Based on the study outlined in this paper, the following conclusions are made:

- The study shows that, reinforced concrete flat slab and steel framed composite floor structure requires total 539 days and 210 days respectively and the time savings of 189 % is achieved in steel framed composite floor structure. The construction of steel framed composite deck floor structure saves time, which leads to an overall savings in net cost.
- The direct cost required for steel framed with composite deck floor is 50.69 % higher than RCC flat slab structure but after considering time related savings it comes down up to 7.69 %.
- The cost comparison reveals that steel framed composite floor structure is an economically viable solution in India.

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